

Future Ecosystem Services in a Southern African River Basin: a Scenario Planning Approach to Uncertainty

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Abstract: *Scenario planning is a promising tool for dealing with uncertainty, but it has been underutilized in ecology and conservation. The use of scenarios to explore ecological dynamics of alternative futures has been given a major boost by the recently completed Millennium Ecosystem Assessment, a 4-year initiative to investigate relationships between ecosystem services and human well-being at multiple scales. Scenarios, as descriptive narratives of pathways to the future, are a mechanism for improving the understanding and management of ecological and social processes by scientists and decision makers with greater flexibility than conventional techniques could afford. We used scenarios in one of the Millennium Ecosystem Assessment's subglobal components to explore four possible futures in a Southern African river basin. Because of its ability to capture spatial and temporal dynamics, the scenario exercise revealed key trade-offs in ecosystem services in space and time and the importance of a multiple-scale scenario design. At subglobal scales, scenarios are a powerful vehicle for communication and engagement of decision makers, especially when designed to identify responses to specific problems. Scenario planning has the potential to be a critical ingredient in conservation as calls are increasingly made for the field to help define and achieve sustainable visions for the future.*

Keywords: conservation decision making, ecological processes, ecosystem services, Millennium Ecosystem Assessment, possible futures, social processes

Servicios Ecosistémicos Futuro en una Cuenca Hidrológica Sudafricana: un Acercamiento a la Incertidumbre Mediante la Planificación de Escenarios

Resumen: *La planificación de escenarios es una herramienta promisorio para tratar con la incertidumbre, pero ha sido subutilizada en ecología y conservación. El uso de escenarios para explorar la dinámica ecológica de futuros alternativos tuvo un impulso trascendental por la Evaluación Ecosistémica del Milenio, una iniciativa de 4 años para investigar las relaciones entre los servicios ecosistémicos y el bienestar humano en escalas múltiples. Los escenarios, como narrativas descriptivas de rutas hacia el futuro, son un mecanismo para mejorar el entendimiento y gestión de procesos ecológicos y sociales por parte de científicos y tomadores de decisiones con mayor flexibilidad que las técnicas convencionales. Utilizamos escenarios de uno de los componentes subglobales de la Evaluación Ecosistémica del Milenio para explorar cuatro futuros posibles en una cuenca hidrológica sudafricana. Debido a su habilidad para capturar dinámicas espaciales y temporales, el ejercicio de escenarios reveló ventajas y desventajas claves en los servicios ecosistémicos en espacio y tiempo y la importancia de un diseño de escenarios en escalas múltiples. En escalas subglobales, los escenarios son un vehículo poderoso para la comunicación y cooperación de tomadores de decisiones, especialmente cuando son diseñados para identificar respuestas a problemas específicos. La planificación de escenarios tiene*

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el potencial de ser un ingrediente crítico en la conservación en respuesta a la necesidad de definir y lograr visiones sustentables del futuro.

Palabras Clave: Evaluación Ecosistémica del Milenio, futuros posibles, procesos ecológicos, procesos sociales, servicios ecosistémicos, toma de decisiones de conservación

Introduction

The future is inherently laden with uncertainty and surprise. In many cases, science and technology have reduced fundamental uncertainties about how the world works, vastly improving our ability to anticipate change, but the elusiveness and unpredictability of numerous aspects of the future remain. This makes the practice of conservation a challenging prospect, and despite our best efforts, all the data, information, and technology we have are unlikely to save us from some unpleasant surprises (McDaniel et al. 2003). There is a need to better embrace the future's uncertainty and to develop mechanisms to elucidate aspects that are difficult to contemplate. This uncertainty is also likely to require a different approach to conservation, taking it beyond its roots in crisis and an "atmosphere of loss and blame" (Redford & Sanjayan 2003) to an expanded view of humans and nature as coupled, coevolved components of social-ecological systems (Westley et al. 2002). Ultimately, we will never know "all" and must therefore design approaches to conservation that are robust under a wide range of possible outcomes.

Fortunately, the focus of scientific assessment is beginning to expand beyond the gathering, analyzing, and synthesizing of information to helping decision makers deal with and respond to uncertainty (Salzman 2005). This shift does not obviate the need for further specific scientific knowledge; rather, it recognizes that stocktaking efforts need to ask both scientists and decision makers to identify key system processes, drivers, and interactions that are most likely to result in surprise. It is in this spirit that scenarios, as narratives that describe alternative pathways to the future, offer a promising collaborative approach for building resilience to the future's unpredictability. The recently completed Millennium Ecosystem Assessment (MA 2003) provided an unprecedented opportunity to develop scenarios of future ecosystem services and their relationships to human well-being at global, regional, and local scales. We discuss the experience, findings, and lessons learned from a scenario analysis of a multinational river basin that formed part of the subglobal Southern African Millennium Ecosystem Assessment (Biggs et al. 2004). We suggest that scenarios deserve more prominence in scientific efforts to understand and manage uncertainty in ecological and conservation decision making.

Scenarios in the Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment was a 4-year program launched in 2001 to meet the needs of decision makers for scientific information about the relationships between ecosystem change and human well-being (MA 2003). In addition to a global analysis, it included 33 sub-global assessments, ranging in size from village to sub-continent, to provide a more detailed picture of ecosystem services and human well-being, build capacity to conduct ecosystem assessments, and strengthen user involvement across the globe. Guided by a user-driven process, it sought to engage ecosystem users and managers and to incorporate their knowledge and perceptions into the assessment. The global assessment served three international environmental conventions, national governments, and the private sector, whereas subglobal assessments addressed the concerns of specific user advisory groups.

Scenarios formed a major component of the Millennium Ecosystem Assessment's work. We define *scenarios* as a set of plausible narratives that depict alternative pathways to the future. Scenario planning is the creation and use of such scenarios in a structured way to stimulate thinking and evaluate assumptions about future events or trends and to make uncertainties about these explicit. It is important to make a distinction between scenarios in this sense and projections, forecasts, and predictions, all of which relate more to the probability than possibility of future outcomes (Peterson et al. 2003). Projections and forecasts—which typically place an estimate on the likelihood of an event's occurrence—work best for short-term forecasting in well-understood systems (Bennett et al. 2003). This is an appropriate way to deal with uncertainty when the objective is risk management, which requires at least an intuitive probability to be placed on the occurrence of a rare event, such as a space shuttle accident (Seife 2003). Ecosystem services and human well-being, on the other hand, are part of social-ecological systems, in which unexpected outcomes are common (Gunderson & Holling 2002).

Scenario planning is most useful for dealing with uncertainty when we lack sufficient information about the probabilities that different events will occur. In the business world, scenarios helped Royal Dutch/Shell navigate unpredictable market shocks in the 1970s and 1980s by envisioning and preparing for a future that no one thought would happen (Wack 1985a, 1985b). Scenario

planning also offers a platform for engaging stakeholders with divergent viewpoints and competing objectives and has succeeded in smoothing potentially contentious situations, such as South Africa's transition to democracy in the early 1990s (Kahane 1992). Although the virtues of scenario planning have long been appreciated in business and other fields, it has not been used widely in ecology or conservation (Peterson et al. 2003). Scenarios with an environmental dimension exist, but these generally have several limitations. Most tend to focus on the impacts of drivers on the environment (European Commission 1999; UNEP 2002) or biodiversity (Sala et al. 2000; Bomhard et al. 2005) and do not incorporate ecological feedbacks or human responses. In addition, existing environmental scenarios have usually ignored cross-scale processes—interactions between global climate, national policies, and local population dynamics, for example. Major ecological problems in recent times have resulted from misunderstanding on how these processes work (Wilson et al. 1999; Gunderson et al. 2002), making a third common shortcoming of scenario exercises especially pertinent—they often exclude regional and local decision makers, despite recent advances in participatory scenario planning methodology (Wollenberg et al. 2000; Waltner-Toews & Kay 2005).

The Millennium Ecosystem Assessment took scenario planning to a new level. A Scenarios Working Group, comprising ecologists, economists, and social scientists representing academia, research institutes, nongovernmental organizations, businesses, and indigenous groups from around the world developed participatory, policy-relevant global scenarios to describe the evolution of ecosystem services, human well-being, and their interactions over the next century. In a departure from previous efforts, they focused specifically on ways in which decisions may drive future ecosystem change, ecosystem change may constrain future decisions, and ecological feedbacks may lead to surprise (MA 2005a). A second defining feature was the multiple-scale nature of the effort, with subglobal scenarios developed concurrently by regional and local assessment teams.

The global scenario analysis entailed a review of existing scenarios, interviews of decision makers, visionaries, and other leaders about their key concerns and hopes for the future, and identification of the major ecological management dilemmas the scenarios could address (Bennett et al. 2005). The Scenarios Working Group ultimately chose to develop new scenarios that would be consistent with assumptions about ecosystem resilience, unlike most existing scenarios (Cumming et al. 2005). Four scenarios, focused on uncertainties related to the extent of globalization or regionalism, and a proactive or reactive approach to environmental problems, evolved from this process. The *global orchestration* scenario depicts a globalized and reactive world, driven by a desire to bring

the world's poor out of poverty as quickly as possible. In the *order from strength* scenario, the world is regionalized, reactive, and driven by a desire for security. The *adapting mosaic* scenario is characterized by a regionalized but proactive society and increasing reliance on local institutions and learning to improve ecosystem management. The *technogarden* scenario describes a globalized, proactive world driven by a pursuit of ecotechnologies (MA 2005a).

At the subglobal scale, each assessment team was free to develop any number of scenarios thought to be plausible in the medium term. This resulted in multiple scenario sets for the subglobal assessments, some related to the global scenarios and some completely different (MA 2005b). Typically created in a participatory fashion, subglobal scenarios were driven by specific assessment issues, world views, and the role of the user group in the assessment process. A distinguishing feature of some subglobal scenario exercises was their use of creative forms of expression such as dramatic performance, often more effective than conventional methods for conveying complex issues to stakeholders (Burt & Copteros 2004).

Building Southern African Scenarios: the Gariep Basin Experience

The Gariep River Basin

The Gariep River basin (665,000 km²), which we define as the area of South Africa and Lesotho drained by the Senqu-Gariep-Vaal river system, contains one of the greatest concentrations of wealth on the African continent, Gauteng Province (the Johannesburg-Pretoria metropolitan area). The basin is a region in transition, owing in large part to South Africa's shift to democratic governance in 1994. This political change was a catalyst for accelerating economic growth, redressing inequitable access to resources under the former Apartheid regime, promoting human well-being, and passing progressive legislation on biodiversity, the environment, and water resources. Current policy trends in the region such as decentralization, multinational resource management, and the establishment of pan-African initiatives such as the New Partnership for Africa's Development all have far-reaching implications for ecosystem services.

The Gariep is the most modified river basin in Southern Africa, with massive undertakings such as the Lesotho Highlands Water Project, the largest transfer scheme in African history, impounding and diverting water to serve the Gariep River's competing uses: irrigation of agricultural lands, urban and industrial demands, and use by people and ecosystems. The basin encompasses South Africa's major cereal production area, the bulk of its mining and coal industries, and two international biodiversity

hotspots (Succulent Karoo and Maputaland-Pondoland-Albany). The Gariep Basin is home to nearly 40% of South Africa's population and all of Lesotho's. These populations range from destitute rural communities that are tightly bound to ecosystem services to highly developed industrialized societies.

The Gariep Basin assessment was conducted by a team of scientists with guidance from a user advisory group consisting of policy makers from agriculture, water management, tourism, and conservation departments of national and provincial governments and researchers working on environmental or conservation policy issues. The team and group met five times over 2 years, initially to discuss the assessment objectives, design, and expected outcomes, and then to tackle increasingly complex issues of trade-offs, scenarios, and interventions. Between workshops, the assessment team undertook more extensive analysis of the focal issues identified by the group, with whom it communicated regularly.

The initial assessment task was to identify major ecosystem services in the Gariep Basin and threats to their continued delivery. The group identified food production, water, and energy from various sources as provisioning services—products obtained from ecosystems—and biodiversity as an essential source of many other services (MA 2003). In a departure from the global Millennium Ecosystem Assessment, the user group argued for the inclusion of mineral services due to their importance as a natural resource in the economy and livelihoods of people in the Gariep Basin. The group cited land-use practices—notably urbanization, industrial and mining developments, agriculture, and forestry—and abstraction and diversion of water resources as the major threats to ecosystem services in the basin (Bobensky et al. 2004). Paradoxically, most of these threatening practices have intended to secure ecosystem services and human well-being, but within the context of a narrow, sectoral approach to natural resource management. Group members cited numerous cases of ecological surprise. For example, massive dams built in the 1960s and 1970s to stabilize the Gariep River's flow regime enabled a blackfly (*Simulium chutteri*) to proliferate and affect livestock operations along the river, imposing severe costs on the precise industry the dams were supposed to benefit (Myburgh & Nevill 2003).

Scenarios explored possible futures for ecosystem services and human well-being in the basin during the years 2000–2030. The user advisory group indicated that the major uncertainties associated with the future of the basin's ecosystems and human well-being are the strength of national governance and civil society. Because these uncertainties resemble those of four well-known global scenario archetypes (Gallopin et al. 1997), we decided to test the applicability of these archetypes to the Gariep Basin, retaining some elements while adapting others to

the finer scale of analysis. The initial scenarios were developed by the assessment team and refined in follow-up workshops with the group. To better understand regional dynamics, we also interacted with a team developing two scenarios for the broader Southern African region (Scholes & Biggs 2004).

The four global scenarios are based on clusters of driving forces such as economic and geopolitical forces and social issues: *market forces* and *policy reform* continue in their current trends, but the former is driven by economic growth and the latter by social and environmental sustainability. *Fortress world* and *local resources* (also called *breakdown*) describe a world driven by a global economy, but in the former there is an increasing preoccupation with national security and in the latter a reliance on local institutions. In our interpretation for the Gariep Basin, the market forces scenario becomes a situation in which national governance and the economy are strong and civil society plays a minor role. Fortress world is a scenario about a collapse of national governance structures, a faltering economy, and a fragmented civil society. In local resources, a strong, self-reliant civil society emerges at local levels in the absence of strong national governance. Policy reform describes a strong, globally linked economy within a sound governance framework balanced by an active civil society. Adapting these global scenario archetypes to the circumstances in the basin had two major advantages: it increased the validity of the scenarios in the eyes of the users and enabled a comparison of similarities and differences between scenarios at the two scales.

In addition to the two main uncertainties, we identified bifurcations of drivers that we believed would distinguish the four scenarios in the Gariep Basin (Table 1): (1) national economic growth, (2) wealth distribution, (3) national social and environmental (including climate) policy, (4) management of HIV/AIDS, (5) birth rate, (6) mortality rate, and (7) urbanization. The user group acknowledged the significance of HIV/AIDS and climate change in future ecosystem services and human well-being in the Gariep Basin. To keep the number of uncertainties manageable, however, we chose to focus only on differences in the management of these issues under the different scenarios and did not consider different HIV/AIDS and climate projections. We assumed for all scenarios that the current high HIV/AIDS prevalence rate in South Africa, among the highest in the world (UNAIDS/WHO 2004), will continue to decrease human capital, divert government resources, and increase dependency burdens (Goldblatt et al. 2002). We assumed for all scenarios that between 1990 and 2050, climate change will raise temperatures by as much as 2° C (IPCC 2001) and will decrease runoff in South Africa by up to 10%, moving progressively from west to east (DWA 2004). This is likely to threaten water availability, food production, and biodiversity in the

Table 1. Key bifurcations in drivers of change that distinguish four scenarios of future ecosystem services and human well-being (adapted from Bohensky et al. 2004).*

<i>Driver</i>	<i>Market forces</i>	<i>Policy reform</i>	<i>Fortress world</i>	<i>Local resources</i>
Political, economic, and social environment				
national governance structures	+	++	—	—
civil society	—	+	—	+
national economic growth	++	+	—	—
distribution of wealth	—	+	—	—
national social and environmental policy	—	+	—	—
HIV management	+	++	—	—
Demographic trends				
birth rate	medium	low	high	high
mortality rate	medium	low	high	high
urbanization	increasing	increasing	increasing	constant

*Symbols: ++, *exceptionally strong*; +, *strong*; —, *weak or nonexistent*.

more arid parts of the basin, although certain crops and species may thrive in other parts (van Jaarsveld & Chown 2001).

We expected the scenarios to manifest differently within the basin and therefore defined four zones based on biophysical and socioeconomic characteristics: (1) urban areas, notably Gauteng Province, which depend to a large degree on ecosystem services from other regions; (2) the “grain basket,” the agriculturally productive grasslands and water-rich highlands; (3) the densely populated, largely rural, and poor Great Fish River; and (4) the “arid west,” a low-rainfall, sparsely populated, mostly rural expanse of land where many mining operations are concentrated.

We experimented with several approaches to describe the implications of the scenario bifurcations for ecosystem services. We first used an integrated dynamic systems model (Erasmus & van Jaarsveld 2002) to generate results, but the user group thought the model—which they had no part in creating—was too complex to elucidate important relationships. We then tried an interactive approach, and asked users to draw arrows to indicate direction and magnitude of change in ecosystem services and human well-being under each scenario relative to current condition. Users struggled to reach agreement, arguing that in attempting to summarize change we were oversimplifying it. Users appreciated the division of the basin into zones but noted important fine-scale differences within zones. For example, food production in South Africa’s grain basket is significantly more commercialized than in Lesotho’s. Essentially, the users’ dissatisfaction lay in the inability of these methods and categorizations to tell the whole story. Users were much more accepting of short narratives of change that had greater flexibility to capture important differences. Later, we used spider diagrams to illustrate trends in these narratives.

Below we summarize the scenario storylines that resulted from our initial translation of the global scenarios, the scenario workshops, and subsequent consulta-

tion with members of the user advisory group. For each scenario, key drivers are identified, followed by a description of their consequences for five ecosystem service categories: biodiversity, energy, food, freshwater, and mineral services (Bohensky et al. 2004). We explore these dynamics in the four regions of the basin defined above and consider how they may differ in Lesotho. We also describe conservation attitudes, opportunities, and constraints in these alternative futures.

Market Forces

Gauteng continues to expand as the commercial and industrial heartland of the basin. Average income rises but so do income disparities between rich and poor. The urban poor benefit marginally from the trickle-down effects of a growing economy. As rural living conditions deteriorate, the rural poor flock to the rapidly expanding peri-urban areas to find employment.

Mining activities expand wherever possible, and agricultural land in Gauteng is rapidly converted to urban or industrial use. Unregulated coal power generation and increased industrial effluent cause water and air pollution and lead to a higher prevalence of water-borne diseases in poor urban populations. South Africa’s entry into free-trade agreements pushes agricultural production toward exports, such as grapes and citrus along the Gariep River. Although food production increases in some regions, the lack of a clear policy framework for climate change decreases household food security for subsistence farmers and the rural poor. Farming on increasingly marginal lands promotes soil erosion. Water is increasingly impounded and diverted for use by cities, industry, and commercial irrigation.

Societal values largely favor development over conservation, and poor enforcement of environmental legislation negatively affects biodiversity, although conservation does benefit in some places from private investment. In Lesotho, siltation that results from the large dams ignites

conflict between farmers who are affected and industries that champion economic growth. Those with an interest in preserving the region's threatened species form an unexpected alliance with the affected farmers to demand compensation for lost ecosystem services.

Policy Reform

Amid socially and environmentally sound governance and regional peace and security, the region sustains high foreign investment. A fair-trade environment promotes its global competitiveness, and a vibrant technology sector supports improvements in infrastructure, health, education, and service delivery.

However, some of the new policies have mixed consequences for ecosystem services. Increased trade encourages intensified agricultural practices and the rapid adoption of genetically modified organisms, pesticides, irrigation technology, and fertilizers, but also creates access to organic farming markets. Increased wealth drives the agricultural sector toward intensive livestock production, with a positive conservation spin-off: game farming operations expand in the basin and are far more compatible with protected areas than the livestock farms they replace. Reduced pressure for land means a favorable outlook for conservation in general. Biodiversity conservation and environmental education are high on the agenda of policy makers. People recognize that climate change is causing more frequent droughts and floods that affect a range of ecosystem services that they value. Water withdrawals and treatment costs increase with economic growth, but the establishment of catchment management agencies and market instruments ensure accountability for water use. Policies on environmental flows and freshwater biodiversity become models for other regions to follow. Coal still dominates the energy sector, but a growing proportion of the basin's urban and wealthy populations power their households with renewable sources—solar power projects flourish in the “arid west.”

Lesotho becomes an attractive ecotourism destination, owing in part to a successful marketing campaign for the Drakensberg-Maloti Transfrontier Conservation Area and the rise of prolific community-run lodges. Yet the rapid influx of tourists challenges the capacity of park managers, and some local residents believe they do not benefit from these initiatives.

Fortress World

The Gariep Basin becomes visibly divided. The wealthy live in security enclaves and rely on imports, while the poor become increasingly impoverished. Lack of access to water, land, and mining rights ignites local tension and conflict across the basin, allowing corporations and the political elite to take advantage of the unregulated and chaotic environment.

The ability of the rural poor to survive in a variable and arid climate is compromised, and many seek employment in cities, where competition for limited jobs is fierce. Others resort to poaching and harvesting of resources in reserves, where cash-strapped conservation departments are unable to enforce legislation, and the region's tourism appeal rapidly plummets. Reduced industrial activity and pollution retard degradation of ecosystem services somewhat, but most gains are offset by government failures to extend electricity and water services to people, forcing them to exploit the limited biofuels and water supplies within their reach.

South Africa defaults on its royalty payments for the Lesotho Highlands Water Project, eroding the financial and energy benefits once provided to Lesotho. Water supplies in Gauteng and beyond become highly stressed. Reductions of water and sediment inflow to the Orange River Mouth Wetland, a Ramsar Site and a BirdLife International Important Bird Area, cause declines in its migratory bird populations, raising concerns among conservationists and hinting at other ecological changes that have not been monitored. This draws little attention from politicians, however, who seem to believe that environmental problems will somehow dissipate on their own.

Local Resources

Despite ineffective national governance, corruption, and economic mismanagement, strong civil society networks form across the basin and encourage local infrastructure development, with community-driven service provision. The rural population, growing steadily and faced with a declining resource base for subsistence farming, becomes increasingly self-reliant.

The remnants of commercial agriculture are sufficient to feed the urban markets but are expanded onto increasingly marginal lands, exacerbating soil erosion. Agricultural diversity provides some resistance to pest outbreaks, although crop failures are common as droughts occur more frequently due to climate change. Local conservation initiatives spring up in places and garner the support of international nongovernmental organizations. With a few exceptions, most local authorities are unable to make the promises of the free basic water and electricity programs a reality. Rainwater harvesting becomes common in many areas, new wells are dug, and community woodlots supply household energy needs. However, national environmental standards are poorly enforced, allowing waste products to be dumped on poor communities across the basin. Water quality deteriorates, sewage is untreated, and mortalities from waterborne disease rise.

Lesotho, in an effort to decrease its economic dependence on South Africa, secures international assistance to increase its agricultural productivity. In a botanical reserve created as part of the Lesotho water project, a local team of biologists discovers an endemic plant with

high pharmaceutical value. Residents lobby for more formal conservation of this biome and stronger legislation to protect intellectual property rights.

Key Findings

The expected direction and magnitude of change in ecosystem services in each scenario and region are described as a sharp increase, a slight increase, no change, a slight decrease, or a sharp decrease in the availability of ecosystem services (Fig. 1). We distinguish between provisioning services, such as food, in which an increase signifies higher levels of service production, and regulating and supporting services, such as biodiversity, in which an increase means an improvement in the condition of the service. Freshwater provides both types of services, but we focused on its regulating services in line with the expanded definition of water resources under the South African Water Act of 1998 (Mackay 2003).

a slight decrease, or a sharp decrease in the availability of ecosystem services (Fig. 1). We distinguish between provisioning services, such as food, in which an increase signifies higher levels of service production, and regulating and supporting services, such as biodiversity, in which an increase means an improvement in the condition of the service. Freshwater provides both types of services, but we focused on its regulating services in line with the expanded definition of water resources under the South African Water Act of 1998 (Mackay 2003).



Figure 1. Change in production or condition of ecosystem services in the four regions of the Gariep Basin from 2000 to 2030 under (a) policy reform and market forces scenarios and under (b) local resources and fortress world scenarios. The amount of change in each service is described as a sharp increase (+2), slight increase (+1), no change (0), slight decrease (−1), or sharp decrease (−2).

The scenario analysis highlighted several key findings of significance to the assessment. One is that trade-offs of several types are ubiquitous in all scenarios and regions. A second is that some, but not all, findings converge with those of the global scenarios, underscoring the importance of a multiple-scale design.

Trade-Offs

Trade-offs, as well as synergies, between ecosystem services and biodiversity are a major conservation concern. The maintenance of some services, such as nature-based tourism, medicinal plants, and crop pollination, has a clear link to biodiversity and provides a strong economic argument for conservation (Ricketts 2004). Biodiversity also has a fundamental link to human well-being in that it enables people, especially the rural poor, to maintain diverse livelihoods based on ecosystem services (Tengö & Belfrage 2004). However, the relationship between biodiversity and many services is often an uneasy one and poorly understood. Our difficulty in deciphering these relationships under the scenarios made this clear and stressed the need for better information on thresholds.

Under most scenarios, a common trade-off is the increase in provisioning services at the expense of regulating and supporting services and biodiversity. This is essentially a trade-off between current and future generations: people can derive benefits from provisioning services now, but this choice may eventually result in a loss of services. This is especially prominent in the market forces scenario, whereas in the policy reform scenario, provisioning services increase but synergistic management across the basin strives to balance the use of these services with the maintenance of regulating and supporting services. Yet policy reform is not a panacea. Policies to intensify agriculture, for example, may embody a command-and-control mentality aimed at maximizing returns rather than maintaining a variety of ecosystem services, and possibly reducing critical system variability over the longer term (Rogers et al. 2000).

Trade-offs may occur between services in space. Freshwater flows and transfers create important interdependencies between regions, and only under policy reform, where water use is effectively regulated by national policy, does it improve throughout the basin. In addition, supply and demand of each ecosystem service have a unique spatial distribution. Trade-offs may occur in areas that have multiple competing services (grain basket), in areas that produce services (grain basket) that are consumed elsewhere (Gauteng), or where ecosystem service use outstrips the capacity of the region to produce it (arid west).

We also observed trade-offs in the ways that societies deal with ecosystem service deficiencies. Affluent and urban populations tend to buffer themselves from shocks and disturbances by using manufactured capital or tech-

nology or consuming ecosystem services from distant places (Lambin et al. 2001). However, over time, a society's dependence on such buffers can increase its vulnerability to change if the buffer is removed (Gunderson et al. 1995). By contrast, poor populations often must be adaptive, adopting coping strategies that enable survival in difficult times, which may help build their resilience (Berkes et al. 2000). An example is temporary migration between urban and rural areas with the ebb and flow of economic opportunities. Yet as urban densities increase, urban quality of life for the poor may decline, eventually drawing people back to their rural homes (Potts & Mutambirwa 1998). This creates an important spatiotemporal dynamic in the demand for ecosystem services that many analyses do not capture.

These different types of trade-offs tend to transfer costs from one individual or society to another. This may be easy when the transferring party is not accountable, such as when the affected party is far away or powerless to intervene. Future generations are therefore common victims (Bohensky & Lynam 2005). Yet sometimes the effects of trade-offs are felt closer and sooner than expected, such as the "surprise" blackfly outbreak noted above. For this reason, scenarios can be effective for illustrating how such surprises might happen and for eliciting users' reactions.

Cross-Scale Convergence

Although there was little true cross-scale integration or nesting of the Millennium Ecosystem Assessment scenarios, some findings of the global and basin scenarios agree; for example, the trade-off between provisioning services and other services is endemic in all scenarios at both scales. Another similarity between the global and basin scenarios is the finding that a high-level governing authority is not always needed to manage all ecosystem services, but the ability to solve problems without it depends critically on the scale of the ecosystem process in question. The local resources scenario contradicts the "tragedy of the commons," suggesting that in the absence of strong central government control, some ecosystem degradation can be avoided through self-governing local institutions (Dietz et al. 2003). However, in this scenario basin-scale measures are needed to protect downstream water resources from upstream impacts, and in the adapting mosaic scenario global interventions are required to govern the global commons (MA 2005a). The policy reform scenario, like technogarden, works in part because people begin to understand the links at all scales between ecosystem services, biodiversity, and human well-being, and coordination between institutions at multiple scales reflects this understanding.

The global and basin scenarios diverge where concepts do not translate meaningfully from one scale to another because of differences in objectives and values. The

most significant differences emerge because the Gariep is largely a developing-world basin, where much debate abounds about where environment and conservation fit on an agenda to promote economic growth and improve social services. Although a policy reform scenario may be possible in parts of Southern Africa, a technogarden type of scenario may be premature, as the user group conveyed early in the process. Such “ground truthing” with stakeholders needs to be done to ensure that scenarios are realistic and consistent (Peterson et al. 2003).

Reflections on a Learning Experience

Although our assessment of current conditions and trends in ecosystem services and human well-being in the Gariep basin draws on information from past studies, the scenario analysis ventures into more unknown terrain; yet many of the assessment’s key findings emerge precisely from peering into the future. This may be because the scenario analysis is the only aspect of the assessment in which space and time are fundamentally integrated. Space and time clearly matter: dynamic issues such as proximity to resources, connectedness to markets, position in the basin, buffer effects, and migration trends all shape these different futures. Tellingly, the uncertainty surrounding the future provoked the most reaction in our user advisory group workshops. Users were usually in agreement about the condition and trends of ecosystem services and current response options, but there was considerably more divergence in our opinions on the “big unknowns” of the future. This lack of consensus challenged us to rethink some assumptions of the assessment and their preliminary findings.

A limitation of the exercise is that it is not intended to inform a focal policy issue or decision. Scenarios are likely to be most beneficial to conservation if developed with the intent of identifying or solving specific problems (Wollenberg et al. 2000). There are numerous examples of issues in the Gariep Basin that would benefit from scenarios. One is the ecological reserve, or environmental flows, determination under South Africa’s National Water Act. This process entails a stakeholder-defined classification of water resources in each catchment according to ecosystem services that they consider of value (Mackay 2003). The use of scenarios would allow stakeholders to explore consequences of managing water along alternative pathways to the future. The Gariep scenarios approach is also being explored to better understand and manage invasive alien species in the region, an issue in critical need of a more integrated spatial and temporal frame (Duke & Mooney 1999; Chapman et al. 2001).

Despite its shortcomings, the scenario exercise exposed a range of individuals and organizations in the region to a new approach to problem solving, and many of

them indicated interest in using the results or approach in their own conservation and environmental initiatives. For the longer term, it has contributed to the knowledge base for scenario planning in an ecological context in the Southern African region. Even though scenarios provoked debate among the user advisory group, some participants stated they were the most exciting and informative part of the assessment because they imparted a sense of ownership, rather than mere spectatorship, of a process that might influence the future (GBN 1998). Scenarios also encouraged them to mentally transcend the boundaries that typically constrain decision making to a narrow range of expectations. Finally, scenarios have a tremendous ability to illustrate and communicate important messages that scientists sometimes take for granted to a decision-making audience, which is often not accustomed to dealing with uncertainty over long time horizons.

Conclusion: Preparing for a Range of Futures

Based on the Gariep Basin scenario experience, we believe that scenarios are a powerful tool for ecology and conservation but cannot understate the need for future scenario exercises to place added emphasis on the engagement of and communication with decision makers and to use the appropriate scales for addressing the problems in question (Reid & Mace 2003). At subglobal scales, we recommend that scenario planners strive to involve and excite people through creative methods and suggest that qualitative storylines may be more accessible than quantitative models and graphics.

Calls are increasingly being made for the science and practice of conservation biology to help define and achieve sustainable visions of the future. Although scenarios offer a promising mechanism, we need to continue to hone our tools for the task. Uncertainty frequently results in crises, but mostly because—inherent though it may be—we are ill-prepared to respond. Through scenarios, scientists and decision makers can collectively embrace uncertainty, prepare for a range of potential futures, and turn would-be crises into opportunities for positive change.

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